Moldflow Summit 2019
General Motors Moldflow Case Studies
The Good, The Bad, and The Ugly

Aaron Leonard (General Motors)
Sr. Manufacturing Engineer | aaron.leonard@gm.com
INTRO

GLOBAL STANDARDS

2019 BLAZER
INTRO – GM VALUES

OUR VISION

ZERO CRASHES
ZERO EMISSIONS
ZERO CONGESTION

ZERO Crashes
Autonomous
1.25M Annual Deaths
90% Human Error

ZERO Emissions
Committed to EV
238 Miles (Bolt)

ZERO Congestion
168 Hours Idle
Sharing (Maven/Lyft)
Cruise Program
## INTRO – APPENDIX E8 COMPONENTS

<table>
<thead>
<tr>
<th>Exterior</th>
<th>Interior</th>
</tr>
</thead>
<tbody>
<tr>
<td>Front Bumper</td>
<td>Instrument Panel</td>
</tr>
<tr>
<td>Lighting</td>
<td>Floor Console</td>
</tr>
<tr>
<td>Rear Bumper</td>
<td>Hard Trim</td>
</tr>
<tr>
<td>Wheel Liner</td>
<td></td>
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</table>
INTRO – GMW STANDARDS

Five Global Engineering Standards Documents

<table>
<thead>
<tr>
<th>GMW15850</th>
<th>Mold Design &amp; Construction</th>
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<tbody>
<tr>
<td>GMW16355</td>
<td>Injection Molding Analysis</td>
</tr>
<tr>
<td>GMW16365</td>
<td>T1 Tryout Protocol</td>
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<tr>
<td>GMW16375</td>
<td>Injection Mold Maintenance</td>
</tr>
<tr>
<td>GMW18157</td>
<td>Tool Steel for Injection Molds</td>
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*New May, 2019*

Available to Download on IHS Website (www.ihs.com)

Standards Enable Kaizen Improvements
INTRO – STANDARDIZED WORK

Moldflow Workflow

Moldflow Inputs

Moldflow Outputs
INTRO – PRIVATE GM DATABASES

Private Material Database

>50 Resins
Full MPL 150 Characterization
Available to All Approved Analysts

Private Machine Database

>110 Molding Machines
T1 Tryout Locations
Available to All Approved Analysts
INTRO – APPROVED LIST & PROCESS

**Tool Source Approval Process**
1. Tier 1 Recommended
2. On-Site Approved
3. Meet GM Requirements
4. Review Ongoing Performance

**Moldflow Source Approval Process**
1. Tier 1 Recommended
2. Autodesk Moldflow Expert Certified
3. Demonstrate Simulation Capabilities
4. Review Ongoing Performance

**Approved Tool Shop List**

**Approved Moldflow Analyst List**
Mold Scorecard
Evaluate Supplier
Validate Mold Quality
Record Multiple Events

Moldflow Scorecard
Evaluate Supplier
Validate Simulation Quality
Record Multiple Events
INTRO – FORMAL KAIZEN ACTIVITIES

GM Pre-Summit

Advisory Board
INTRO – GMW16355 TRAINING

American Injection Molding Institute by Beaumont

GMW16355 General Motors Worldwide Engineering Standard for Moldflow®

Learn how to optimally direct simulation analysis initiatives and get the maximum value from the results while satisfying the requirements of the GM Flow Simulation specification GMW16355.

This 2-day course is applicable to both Moldflow and non-Moldflow users. We will discuss plastic engineering principles coupled with the application of injection molding simulation software.

Course Highlights
- Plastic Rheology
- Cooling Design + Optimization
- Thermoplastic Shrinkage & Warpage
- Root Cause Diagnostic Approaches
- Results Interpretation
- Modeling
- Mesh Optimization
- Analysis Techniques
- Critical Inputs

About the Instructor
- GM Certified Moldflow® Analyst
- Moldflow® Certified Expert

Jennifer Schmidt
Senior Instructor, Simulation
AIM Institute

When: July 30-31 (Sold Out!)
October 2-3

Location: Novi, MI

Price: $600

https://aim.institute/moldflow/gmmoldflow/
THE GOOD

2020 SILVERADO HD
THE GOOD – DEFINITION

Team Made **Upfront** Simulation-Driven
Part Design, Process, and/or Mold
Changes That Improved Part Quality
**THE GOOD – EXAMPLE 1**

**Item:** Controlling Flow Front by Gate Selection and Valve Gate

**Goal:** Reduce Flow Length and Manage Weld Lines

- Instrument Panel
- Fascia
- Door Trim
- Floor Console
THE GOOD – EXAMPLE 1 (DETAILED)

Part: Instrument Panel Retainer
Result: Weld Lines Managed to Non-Visible Areas

<table>
<thead>
<tr>
<th>#</th>
<th>Time (sec)</th>
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<tbody>
<tr>
<td>1</td>
<td>0.00</td>
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<td>1</td>
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<td>2</td>
<td>0.55</td>
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<tr>
<td>3</td>
<td>1.97</td>
</tr>
<tr>
<td>4</td>
<td>2.42</td>
</tr>
<tr>
<td>4</td>
<td>2.42</td>
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<tr>
<td>4</td>
<td>2.42</td>
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<td>5</td>
<td>2.62</td>
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<tr>
<td>6</td>
<td>3.47</td>
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<tr>
<td>7</td>
<td>3.93</td>
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</table>
THE GOOD – EXAMPLE 2

Item: Controlling Flow Front by Part Thickness
Goal: Manage Weld Lines/Air Traps and Improve Fill Balance
Part: 2-Shot Headlamp Lens
Result: Move Gas Trap to Area That Can Be Vented

Original

Cannot Vent

Revised

Can Vent
THE GOOD – EXAMPLE 3

**Item:** Applying Mold Compensation (Windage)

**Goal:** Modify Mold Geometry to Counteract Predicted Warpage
THE GOOD – EXAMPLE 3 (DETAILED)

Part: Interior Structural Part
Result: Added Windage to Achieve Near Net Design Dimensions

Moldflow Warpage

Add Windage

Final Warpage

Warp Up (~4-5mm)

Windage Down (~3mm)

Final Results Near Net
THE GOOD – EXAMPLE 4

Item: Optimizing Cooling by Various Techniques
Goal: Improve Cooling Design and Efficiency

Thermal Insert  Conformal Cooling  Thermal Insert  Cooling Optimization
THE GOOD – EXAMPLE 4 (DETAILED)

Part: Rear Fascia
Result: Improved Uniform Mold Temperatures by 30%
THE BAD
THE BAD – DEFINITION

Team Misunderstood or Ignored Predicted Simulation Recommendations That Resulted in a Less Than Flawless Launch
THE BAD – EXAMPLE 1

Part: Lift Gate Trim
Issue: Moldflow Predicted Large Warpage and No Action Taken

Large X-Axis Warpage

Gap and Flush Issues
**THE BAD – EXAMPLE 1**

- **Solution:** Major Part Changes
- **Result:** Reduced Warpage From ~13mm to ~5mm

<table>
<thead>
<tr>
<th>Item</th>
<th>Cost</th>
<th>Days</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clip Interference</td>
<td>$25,530</td>
<td>14</td>
</tr>
<tr>
<td>Tower Height</td>
<td>$18,525</td>
<td>8</td>
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<tr>
<td>Part Thickness and Styling Change</td>
<td>$57,250</td>
<td>21</td>
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<tr>
<td><strong>Total</strong></td>
<td><strong>$101,305</strong>*</td>
<td><strong>43</strong>**</td>
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</tbody>
</table>

*Does Not Include GM’s Internal Cost and Time

**Took 140 Days to Identify Problem**
LESSON LEARNED

Tip: Apply Shrinkage Compensation to Deflection Results
Revised: Added TIS 3.1 #30 to Evaluate Out of Shape Warpage

Shrinkage Compensation

Use Tool Shrinkage Rate
**Do Not Use Automatic**

Do Not Take Dimensions Across Part
THE BAD – EXAMPLE 2

Part: Structural

Goal: Moldflow Predicted Large Warpage and No Action Taken
### THE BAD – EXAMPLE 2

<table>
<thead>
<tr>
<th>Solution:</th>
<th>Added Windage After Mold Construction and Molding</th>
</tr>
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<tbody>
<tr>
<td>Result:</td>
<td>Reduced Warpage From ~11mm to ~1mm</td>
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</table>

<table>
<thead>
<tr>
<th>Item</th>
<th>Cost</th>
<th>Days</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 Windage Iterations</td>
<td>$60,000</td>
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<tr>
<td>Multiple Tryouts</td>
<td>$4,000</td>
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<tr>
<td><strong>Total</strong></td>
<td><strong>$64,000</strong>*</td>
<td><strong>40+</strong></td>
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*Does Not Include GM’s Internal Cost and Time
LESSON LEARNED

Tip: Use Path Plot to Determine Warpage Causes
Revised: Added TIS 3.1 #31 Evaluate Path Plots for GD&T
THE BAD – EXAMPLE 3

Part: Rear Fascia
Issue: Unacceptable Weld Line

Weld Line ~0.04mm 0 Degree
**THE BAD – EXAMPLE 3**

Solution: Added Gate and Filled in Hole  
Result: Relocated and Eliminated Weld Lines

<table>
<thead>
<tr>
<th>Item</th>
<th>Cost</th>
<th>Days</th>
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<tbody>
<tr>
<td>Mold Change</td>
<td>$170,000</td>
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</tr>
<tr>
<td>Resin Piece Price^</td>
<td>$10,800</td>
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<tr>
<td>Punch Cost^</td>
<td>$250,000</td>
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<tr>
<td>Punch Piece Price^</td>
<td>$679,200</td>
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<tr>
<td><strong>Total</strong></td>
<td><strong>$1,110,000</strong>*</td>
<td>50+</td>
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</table>

*Does Not Include GM’s Internal Cost and Time  
^Cost Required to Make Good Part Was Unexpected
Tip: Review Velocity Vectors at Weld Lines

Revised: Investigating Required Standard Updates

LESSON LEARNED

Top View – Before Weld | Top View – After Weld | Section View

Hard Weld Lines

Soft Weld Lines

Review Velocity in Addition to Pressure, Temperature, and Angle
THE BAD – EXAMPLE 4

Part: Rear Fascia
Issue: Unacceptable Sink Marks

Mid-Plane Sink Mark Depth

Sink Marks
THE BAD – EXAMPLE 4

Solution: Removed Ribs
Result: Eliminated Sink Marks

<table>
<thead>
<tr>
<th>Item to Fix</th>
<th>Cost</th>
<th>Days</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mold Change</td>
<td>~$25,000</td>
<td></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>~$25,000*</td>
<td>~20</td>
</tr>
</tbody>
</table>

*Does Not Include GM’s Internal Cost and Time

Removed Ribs (32 Places)
LEsson LEarned

Tip: Define Allowable Sink by Correlating Moldflow to Actual
Revised: Revising TIS 3.1 #20 Sink Mark Guidelines

Pin  Boss  1  1.3  2.3  3
THE UGLY
Team Unaware of Defects Due to Inaccurate Model Settings That Resulted In Unexpected Launch Issues
THE UGLY – EXAMPLE 1A

Part: Interior Part
Issue: Excessive Pressure Predicted

12,956 psi

9,928 psi
THE UGLY – EXAMPLE 1B

Part: Long Fiber Interior Part
Issue: Inaccurate Warpage

MFR Communicator Log Error
The material selected for this analysis is a long-fiber-filled material, a short fiber orientation model should not be used for the long fiber orientation. Continuing analysis with the selected fiber orientation model.

AMI 2019 Includes Fiber Orientation Inside Resin .udb
THE UGLY – EXAMPLE 2

Part: Fascia
Issue: Unacceptable Sink Mark

Final Report
No Sink Mark Identified

Measured Part
~0.044mm Deep Sink Mark
## THE UGLY – EXAMPLE 2

**Solution:** Welded Core Side to Core Out Thick Area

**Result:** Eliminated Sink Mark

<table>
<thead>
<tr>
<th>Item to Fix</th>
<th>Cost</th>
<th>Days</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mold #1 Change</td>
<td>$25,000</td>
<td></td>
</tr>
<tr>
<td>Mold #2 Change</td>
<td>$25,000</td>
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</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>$50,000</strong>*</td>
<td>~30</td>
</tr>
</tbody>
</table>

*Does Not Include GM’s Internal Cost and Time

*Weld Core*
Tip: Create and Analyze 3D Volumetric Shrinkage Sections

Revised: Refining TIS 1.0 Rolling Ball Requirements
THE UGLY – EXAMPLE 3

Part: 3-Shot Tail Lamp Lens
Issue: Unacceptable Sink Mark

Similar Part

1st & 2nd Shots 3rd Shot

Black
Clear

Red
THE UGLY – EXAMPLE 3

<table>
<thead>
<tr>
<th>Item to Fix</th>
<th>Cost</th>
<th>Days</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mold Change</td>
<td>$60,000</td>
<td></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>*<em>$60,000</em></td>
<td>~30</td>
</tr>
</tbody>
</table>

*Does Not Include GM’s Internal Cost and Time

Solution: Reduced Thickness of Red Shot at Frame
Result: Eliminated Sink Marks

Before

After
Tip: Evaluate 2-Shot Parts by Over-Molding or 2-Shot
Revised: Adding TIS 3.1 Requirement for Multi-Shot Molding
THE UGLY – EXAMPLE 4

Part: Door Trim Speaker Grille
Issue: Unacceptable Weld Lines

Initial Moldflow Dual Domain
Final Moldflow Mid-Plane

No Weld Predicted

Molded Part
Weld Line
### THE UGLY – EXAMPLE 4

**Solution:** Increased Thickness and Moved Gate

**Result:** Improved Weld Line Strength and Appearance

<table>
<thead>
<tr>
<th>Item to Fix</th>
<th>Cost</th>
<th>Days</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mold Change</td>
<td>$10,000</td>
<td></td>
</tr>
<tr>
<td>Tryouts</td>
<td>$2,000</td>
<td></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>$12,000</strong></td>
<td><strong>~40</strong></td>
</tr>
</tbody>
</table>

*Does Not Include GM’s Internal Cost and Time

Mid-Plane With Correct Shape Factor

![Weld](image)
LESSON LEARNED

Tip: Use Correct Shape Factor for Speaker Grille Modeling

Revised: Investigating Requiring 3D Mesh for Phase 4 Moldflow

Equivalent Thickness = \( \frac{\text{Volume of Area}}{\text{Projected Area}} \)

Shape Factor = \( \frac{\text{Grille Contact Area}}{\text{Model Contact Area}} \)

Mesh Type | Shape Factor
---|---
Mid-Plane | Must Calculate
Dual Domain | Cannot Simulate
3D Tetra | Auto

Review Moldflow Help

Images Courtesy of Matthew J. Jaworski and Zhongshuang Yuan, Moldflow Corporation
BONUS MATERIAL
How Do You Determine the Accuracy of Your Moldflow Analysis?
CORRELATION – FINAL SCORE

<table>
<thead>
<tr>
<th>Phase</th>
<th>Min. Score</th>
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<tbody>
<tr>
<td>4A/B</td>
<td>70</td>
</tr>
<tr>
<td>5</td>
<td>80</td>
</tr>
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</table>
CORRELATION – PROCESS SCORE

General Info
- Phase 4A: 92%
- Phase 4B: 92%
- Phase 5: 98%

Process
- Phase 4A: 58%
- Phase 4B: 70%
- Phase 5: 78%

Dimensional
- Phase 4A: 0%
- Phase 4B: 33%
- Phase 5: 30%

Appearance
- Phase 4A: 91%
- Phase 4B: 91%
- Phase 5: 88%
CORRELATION – PROCESS DETAIL

Over Predict Gate Freeze

Large Pressure Variations

Over Predict Pack/Hold Time

Phase 4A
Phase 4B
Phase 5
CORRELATION – APPEARANCE DETAIL

- Flash / Parting Line
- Flow Line
- Tiger Striping
- Pin / Lifter Marks
- Other Defect
- Splay/Streaks/Blush
- Sinks / Read Thru
- Ghosting
- Blister / Delamination
- Short Shot
- Jetting
- Bubbling
- Gas Burn (Air Trap)
- Wavy Surface / Warp
- Knit / Weld Line

Graph showing correlation between over predicted and did not predict appearance defects.
# MOLDFLOW TOOLS

<table>
<thead>
<tr>
<th>GM Moldflow Tool Kit</th>
<th>Process Sheets Moldflow Machine</th>
<th>Warpage Query Tool</th>
</tr>
</thead>
</table>

**GM Moldflow Tool Kit**
- General Motors - Moldflow User Tools
  - Switch Tools
  - Quick PDF from FID
  - Thickness Plot
  - Read Log File
  - Geneva
  - Occurrence Plot
  - Access File

**Process Sheets Moldflow Machine**

**Warpage Query Tool**
- Single Chart
- Multi Chart
- Force Chart
- Query Chart
- Multi Chart Query Chart
- Query Chart
TAKE-AWAY CONCLUSIONS

1. Act on Moldflow Results
2. Utilize 3D Mesh
3. Perform Gate Freeze Study Correctly
2020 C8 CORVETTE